

Canada-B.C.

Conservation and Renewable Energy Demonstrations

B.C. 22



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Province of
British Columbia

Ministry of
Energy, Mines and
Petroleum Resources
CONSERVATION AND
TECHNOLOGY DIVISION

DISTRICT OF SURREY AUTOMATED
ENERGY MANAGEMENT PROJECT
REPORT

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B.C. Ministry of Energy, Mines and Petroleum Resources

Canada/B.C. Conservation and Renewable
Energy Demonstration Agreement

**CANADA/BRITISH COLUMBIA CONSERVATION
AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT**

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources - oil and natural gas - are becoming less accessible and more costly. However, Canada is well-endowed with non-renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of British Columbia and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement. The Agreement is dedicated to the development and demonstration of conservation and renewable technologies.

The objectives of CREDA are:

- o To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- o To develop broad public awareness of the potential of renewable energy and conservation technology.
- o To provide opportunities for the commercial application of the technologies within B.C.
- o To create economic spin-off benefits for manufacturing, industry and commerce.
- o To create employment in new or existing energy-related industries.

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ABSTRACT

This report describes the computerized building energy management system (BMS) demonstrated in buildings owned and operated by the Municipality of Surrey, British Columbia during 1982 and 1983.

A Johnson Control JC/85/10 energy management computer was connected to seven separate buildings via telephone lines. The buildings represent five building types.

This report includes tables summarized from an independent consultant's evaluation with present data on energy performance before and after installation of the system in each building.

Conclusions are drawn from the demonstration and recommendations are made for future government support of BMS demonstrations.

EXECUTIVE SUMMARY

The Municipality of Surrey was given a contract under CREDA in November 1981 to install a computerized building energy management system (BMS) at a central location with which to monitor and control the energy use in seven separate and different civic facilities via telephone lines.

The demonstration had three objectives:

1. To establish the feasibility of centralized control via telephone lines.
2. To collect energy performance data and determine effectiveness of a BMS.
3. To reduce energy costs to the municipal government.

It took almost six months for the BMS to be fully installed in the facilities and an additional six months to "debug" it.

An independent consultant was hired to evaluate the system's performance in each building and determine its cost-effectiveness. Two periods of energy use were compared in the evaluation: May 1981 to April 1982 was the "base year"; and, September 1982 to August 1983 the "demonstration year".

The BMS was installed for a total capital cost of about \$123,000 and produced a first year energy cost savings of \$38,600—yielding an average simple payback of 3.2 years. The payback periods ranged from 1.3 to 19.7 years.

It was concluded that the demonstration successfully attained its objectives and it is recommended that the federal government provide further support to BMS demonstrations.

I. INTRODUCTION

In February 1981 representatives of the District of Surrey submitted a proposal to the B.C. Ministry of Energy, Mines and Petroleum Resources for CREDA funding to demonstrate a computerized energy management system in municipal buildings. Specifically, it was proposed that a centrally located computer should be used to control energy use in remote facilities via telephone lines.

Initially, the CREDA demonstration was to be one stage of a three stage program to automate the control of energy in all District of Surrey operations. In Stage I, nine buildings were to be managed from a central control centre; in Stage II an additional seven buildings were to be added, and in Stage III, the computer system was to be upgraded and further expanded to control Surrey's traffic signals.

This ambitious plan was reduced in scale to reflect available funding and also to ensure that a thorough preliminary evaluation could be undertaken first. A total of seven different facilities representing five types of buildings were selected. Included were:

- 2 Libraries
- 2 Swimming Pools
- Municipal Office Building
- Court House
- Law Enforcement Building (open 24 hours)

Although computerization and automation of building energy management had been demonstrated successfully already, this project was considered a suitable CREDA demonstration for three reasons:

1. Central Control of Remote Facilities

Successfully demonstrating the management of remote facilities from a central control point could benefit many public and private sector building managers, e.g. municipal governments, school districts, commercial buildings operators.

Telephone lines were to be the communication medium in this demonstration, but a wireless system of controlling remote facilities would also have been technically feasible.

2. Evaluation of Cost Effectiveness

Since computerized building management was becoming more popular but corresponding information about appropriate applications was virtually non-existent, this demonstration could answer questions about cost-effectiveness, particularly regarding energy management applications.

3. Energy Cost Avoidance

The District of Surrey annually spends over \$500,000 for energy (heat and light) in its facilities. The demonstration was estimated to cost a total of \$110,000 to install but expected to save in excess of \$35,000 annually - a three year payback.

II. DESCRIPTION OF DEMONSTRATION

A. Description of Buildings

Seven municipal buildings with a total floor area of about 19,500 m² and representing five different types of buildings were selected for the demonstration.

Building Description

	Type	Floor Area (m ²)
1. Municipal Hall	4 Storey	4,972
2. Justice Building	2 Storey	1,022
3. Whalley Library	2 Storey	985
4. Centennial Library	2 Storey	2,421
5. North Surrey Pool		
	Pool - 2 Storey)	5,874
	Arena - 1 Storey)	
6. South Surrey Pool	1 Storey	1,952
7. RCMP Building	2 Storey	2,323

A full description of each building's major energy use system is presented in Appendix A.

B. Description of Building Management System (BMS)

The particular BMS model selected for the demonstration was a Johnson Control JC/85/10 energy management computer.

The system hardware consists of five components:

1. A Central Processing Unit (CPU)

This is the "brain" of the central computer. It processes information from the remote facilities and transmits appropriate instructions to the energy systems under its control.

2. Field Processing Units (FPU)

These collect information from the field sensors in each building, transmit this information to the CPU and then carry out any instructions received from the CPU.

3. Field Equipment Units (FEU)

These house transducers used to monitor the field sensors.

4. Field Sensors

These are specific "points" in each building controlled by the computer for example, light switches.

5. Printer

This produces hard copy records as well as a log of all energy management activities.

The CPU is a microprocessor based computer with 64K (kilobytes) of random access memory (RAM) that monitors and controls energy consumption in the various buildings. Software is located in a single disk drive attached to the CPU. A CRT display monitor with special formatting and highlighting features provides a "soft" copy of all BMS activities for immediate reference. The CRT page format allows each of the 20 CRT "pages" to display all 16 points contained in the FPU.

The Surrey BMS incorporates a total of seven FPUs with a maximum capacity of 360 points of which only 50 points are being utilized for the demonstration.

The CPU is centrally located at the Building Maintenance Headquarters and is connected to a FPU in each of seven buildings via leased B.C. Telephone lines.

Integral 1200 BAUD modems in the FPUs allow the receipt and transmission of information back and forth between the CPU and remote FPUs.

Within each building, the FPU is hard wired to each piece of equipment that is monitored or controlled (i.e. points).

The FPU's monitor the points and transmit the information back to the CPU where it is "processed" and the individual software programs drive the CPU to respond to the information received by sending the appropriate signals back to the FPU's.

C. Building Management System Control Functions

The system performs the following six functions:

1. Stop/Start

The CPU starts or stops individual pieces of equipment at predetermined times during each day for a complete calendar year.

2. Temperature Compensated Duty Cycling

This function allows the individual fans to be cycled on and off during the normal working hours. The analog space temperature sensors provide the necessary feedback to the CPU so the duty cycle periods can be overridden if the space temperature drifts out of its predetermined range. In operating swimming pool systems, the relative humidity in the pool area must be maintained at a fixed level. When the humidity rises above 65% the fans remain on until it is reduced back to the setpoint.

3. Supply Air Reset

This function allows the CPU to reset the individual air system supply temperatures to the optimum levels required to satisfy space conditions.

4. Supply Water Reset

This function allows the CPU to control the pool water heaters so that the water temperature is maintained within an optimum predetermined range.

5. Optimal Stop/Start

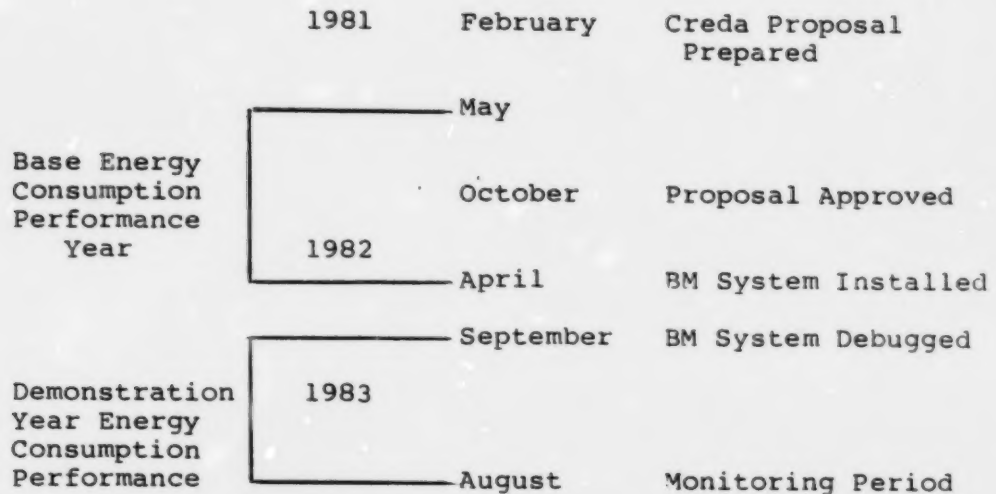
This function utilizes the temperature of an outside air sensor located at the Municipal Hall to stop and start the individual air systems earlier or later in each day according to the individual building's needs.

6. Demand Limiting

This function gives the CPU the capability to load-shed preselected loads at critical times each day in order to limit peak demand charges. This function has not been implemented to date.

The individual points controlled by the BMS are listed in Appendix B.

D. Demonstration Timetable



The demonstration period was officially completed in the fall of 1983. Energy performance data collected for the period September '82 - August '83 during which the BMS was fully operational was compared with a "Base Year" period May 1981 - April 1982. All data were "normalized" to ensure that only the effects of the BMS on energy use were identified - not weather or other factors. This normalization procedure is further discussed in the next section of this report and the procedure for normalizing data is fully described in Appendix C.

III. OBSERVATIONS DURING INSTALLATION & MONITORING

During the installation period several problems arose that could be avoided in future demonstrations.

1. Incompatible telephone lease lines with the CPU and FPU's.

This difficulty took about four months to resolve satisfactorily and could be avoided in the future if the BMS manufacturer is required to ensure the compatibility of his equipment with the existing telephone lines.

2. Lack of user knowledge about the equipment.

The manufacturer must be required to provide sufficient information to permit the safe and efficient operation of all equipment in all circumstances and settings. This should be a condition clearly detailed in all contracts to avoid damage to equipment.

For example, in the Surrey demonstration, it was found that the BMS's emergency power supply was wired for and intended to operate the actual computer equipment only, and not the computer's internal cooling fan. During a power interruption the BMS overheated and damaged the computer.

3. Operating software and procedures must be kept simple.

The BMS must be easily usable by all building operators, to avoid the whole operation becoming dependent upon only one trained individual.

Increasingly manufacturers are producing systems which are more "user friendly" i.e. easier to use. In choosing a system simpler systems should be selected where other characteristics are similar.

IV. COST BENEFIT ANALYSIS

A. Summary of Analysis*

Table 1 Summary of Analysis

Building Name	Floor Area (m ²)	Capital Cost of BMS (\$)	Annual Savings		Total Annual Savings (\$)	Simple Payback (yrs.)
			Nat.Gas (\$)	Elec. (\$)		
Municipal Hall	4,972	27,012	7,531	14,320	21,851	1.24
Justice Bldg.	1,022	14,735	387	362	749	19.7
Whalley Library	985	12,277	525	1,090	1,615	7.6
Centennial Library	2,421	22,102	784	3,497	4,281	5.2
N.Surrey Pool	5,874	9,822	5,756	- 1,926	3,830	2.6
S. Surrey Pool	1,952	14,735	5,957	- 1,011	4,946	3.0
RCMP Building	2,323	22,103	883	460	1,343	16.5
Total	19,549	122,786	21,823	16,797	38,615	3.2 (Avg)

* Energy Savings calculations were based upon \$0.387/Billing Unit for natural gas and \$0.0359/kWh for electricity including demand charges.

The BMS was installed for a total capital cost of about \$123,000 and produced a first year energy cost savings of \$38,600 yielding an average simple payback of 3.2 years. Table 1 summarizes the capital cost investments, savings and paybacks for each building involved in the installation. Capital cost investments include the retrofit costs such as hardwiring the energy use systems to the FPU.

The simple payback periods vary from 1.3 years for the Municipal Hall to 19.7 and 16.5 years for the Justice and RCMP Buildings respectively. The Whalley and Centennial Libraries generate 7.6 and 5.2 year paybacks while the North and South Surrey Pools generate 2.6 and three year paybacks respectively.

B. Method of Analysis

Two equal periods had to be selected for analysis in order to establish what, if any, effect the installation of the BMS had on energy consumption in the seven buildings. The period May 1981 to April 1982 was selected as the "Base Energy Consumption Performance Year" - the year preceding the installation of the BMS. The period Sept. 1982 to August 1983 was selected as the demonstration year because the BMS had been debugged and was fully operational.

The selection of these periods was necessitated by:

1. A ten week civic workers' strike during the spring of 1981 which closed down many municipal operations.
2. A five month "debugging" period from April to Sept. 1982 during which time the energy consumption data were unusable.

In order to make valid comparisons between these two periods and to ensure that only the effect of the BMS on building energy consumption is isolated, the energy consumption data must be "normalized" i.e. the effects of different weather on energy consumption must be eliminated.

Following is a brief description of the two normalization procedures.

1. Normalization for Reading Date Differences

Since natural gas and electricity meters are normally not read on the same day each month and sometimes consumptions are only estimated and billed accordingly or are not billed at all for several months, a calculation procedure must be used that will determine as accurately as possible the actual amount of energy consumed in a given month for each fuel type.

Energy consumption data including delivery date, meter reading date, etc. for each building for a three year period was fed into a computer which performed the normalization calculation. The results were converted to equivalent kWh (EkWh) to permit comparisons.

2. Normalization for Weather Differences

An energy consumption figure can have 2 components: one is sensitive to changes in weather the other is not. It is necessary to distinguish between these components if one is to compare the energy consumption performance of a building from one year to the next.

The standard weather year used is a 30 year average for the Vancouver International Airport. Each year analyzed has its weather sensitive component normalized relative to the standard base reference year.

In order to determine the non-weather sensitive component of energy, the lowest natural gas consumption figure experienced during the summer was considered the base consumption. During this time of the year, heating energy that is sensitive to weather changes should be at a minimum and only those loads independent of weather such as domestic hot water, reheat and pool water heating comprise the majority of the natural gas consumption.

The annual non-weather sensitive component is calculated by multiplying the base month consumption by 12. The raw weather sensitive component is then determined by subtracting the non-weather sensitive component from the annual total natural gas consumption.

This procedure is illustrated in Appendix C.

C. Analysis of Building Energy Management Changes

The analysis had to account for any malfunctioning equipment such as gas meters and the effect of changing programs within the facilities. Also, estimates of energy consumption had to be made in situations where a utility was common to several buildings. Table 2 below describes total energy consumption before the installation of the BMS and after for each building.

TABLE 2 SUMMARY OF ENERGY CONSUMPTION FOR 12 MONTH PERIOD
BEFORE (MAY 81 - APRIL 82) AND AFTER (SEPT. 82 - AUG. 83) BMS INSTALLATION

BUILDING	NATURAL GAS (KWH)				ELECTRICITY (KWH)				TOTAL (KWH)		CHANGE	
	Norm. Weather Sensitive		Non-Weather Sensitive		Before		After		Before	After		
Municipal Hall	Before	After	% Change	Before	After	% Change	Before	After	% Change	Before	After	
	597,664	427,168	- 28.5	763,176	332,448	- 56.4	1,494,150	1,095,264	- 26.7	2,854,990	1,854,880	- 35
Justice Bldg.	-	-	-	-	-	-	128,142	118,056	- 7.9	128,142	118,056	- 7.9
Whalley Lib.	98,950	62,431	- 36.9	9,108	3,732	- 59.0	307,463	277,090	- 9.9	415,521	343,253	- 17.4
Centennial Library	194,281	140,956	- 27.4	14,652	5,424	- 63.0	657,772	560,352	- 14.8	866,705	706,732	- 18.9
N. Surrey Pool	2,176,834	1,058,698	- 51.4	938,364	1,596,960	- 70.2	1,826,900	1,880,542	10.0	4,942,098	4,536,200	- 8.2
S. Surrey Pool	994,144	1,031,830	3.8	1,605,876	1,092,612	- 32.0	827,263	855,429	3.4	3,427,283	2,979,871	- 13.1
RCMP Building	-	-	-	-	-	-	661,665	648,846	- 1.9	661,665	648,846	- 1.9
Justice & RCMP Bldg. Combined	672,214	643,880	- 4.2	437,280	364,248	- 16.7	-	-	-	1,109,494	1,008,128	- 9.1

- Notes:
- Both natural gas and electricity consumptions have been normalized to reflect meter reading differences.
 - Natural gas consumption has been divided into weather sensitive and non-weather sensitive components with the former being normalized for annual degree day differences.
 - Degree Days used are degrees below 18°C for Vancouver International Airport.

1. Municipal Hall

Table 2 illustrates that the Municipal Hall has experienced a dramatic decline in all three components (weather sensitive, non-weather sensitive, and electricity). A possible explanation for the large decline in the non-weather sensitive (-56.4%) could be attributed to better space temperature control resulting in less reheat energy being consumed. Also, duty cycling may also have played a large part in this reduction, as indicated by the 26.7% decline in electrical consumption.

Note: A total of 24,360 kWh was deducted from the "before" period and 36,540 kWh from the "after" period because a new addition was being constructed and this energy was purchased by the contractor.

2. Justice and RCMP Buildings

The Justice and RCMP Buildings are metered separately for electricity but they share a common natural gas meter. Hence the electrical consumption changes are shown individually and the natural gas consumption differences are shown as a combined change.

The Justice Building showed an 8% drop in electricity consumption while the RCMP Building showed only a 2% drop being a 24 hour use facility. The combined natural gas consumption dropped 9% with the weather sensitive and non-weather sensitive components both showing predictable reductions.

3. Whalley Library

A composite "consumption year" had to be created for the Whalley Library. A natural gas consumption meter malfunctioned for about eight months during 1981. Since a full twelve months of natural gas consumption was required before the BMS installation, 1980 was chosen as the base comparison year having only 2.6% more heating Degree Days than May 1981 through April

1982.

Unfortunately, the November and December 1980 electrical consumption readings were suspect so the May 1981 through April 1982 monthly electrical consumption figures were used instead.

Table 2 shows an estimated reduction of 37% in the weather sensitive component and 59% in the non-weather sensitive component. Electricity was estimated to be reduced by 10%.

4. Centennial Library

Gas consumption in both the weather sensitive and non-weather sensitive components declined by 27% and 63% respectively.

Non-weather sensitive reduction is likely attributable to the dramatic reduction in operating time for the three rooftop units serving the multi-purpose room and the reduction in the reheat energy consumed by the rooftop multizone unit serving the Library.

5. North Surrey Pool

The North Surrey Pool and the Arena Complex are both served by the same electricity and natural gas consumption meters. For purposes of this analysis the total floor area of the entire complex was used in calculating energy savings.

Table 2 shows that the weather sensitive component was reduced by 51% which reflects the reduction in makeup air required for the pool. The unexpected change was a 70% increase in non-weather sensitive natural gas consumption. The explanation for this increase is probably the result of increased attendance in pool use between 1981 and 1982 of 50,898 (212,959 - 162,061) persons i.e. 31.4% and the increased arena attendance 111,067 (199,903 - 88,836) i.e. 125%. There has been an increase in 1983 also but annual totals are not yet available. An increase in attendance would affect the non-weather sensitive natural gas consumption in several ways: the pool water heating and domestic hot water consumption would reflect a comparable increase as the water change rate would be increased and more showers would be taken. The arena has a 3,000 - 3,500 imperial gallon

hot water tank which is required to be kept hot for ice surface preparation. This load would likely double with the increased traffic.

Finally the electrical consumption increase of 10% may be attributable to longer ice and pool times. It is very difficult to isolate the effects of these program changes because of common metering and the way in which attendance records are maintained on an annual people flow basis rather than monthly breakdowns.

6. South Surrey Pool

The South Surrey Pool also experienced some very interesting changes between the three components of energy consumption. The pool attendance increased by 12,199 (213,406 - 201,207) persons, i.e. 6% between 1981 and 1982 with a larger increase in 1983 for which statistics are not yet available. The weather sensitive component increased by about 4% while the non-weather sensitive component of the natural gas consumption was reduced by 32%. Several possible explanations may account for these anomalies. The BMS is programmed to run the main Pool multi-zone air system according to the following schedule:

<u>ON</u>	<u>OFF</u>	<u>DUTY CYCLE</u>		<u>DAYS</u>
		<u>OFF</u> (min)	<u>ON</u> (min)	
05:00	22:30	10	20	2,3,4,6,(holidays)
05:00	23:59	10	20	5
08:30	22:00	10	20	1,7

The BMS will override the above schedule and operate the pool air system introducing 100% outside air whenever the relative humidity is greater than 65% in the Pool area.

Six ceiling fans were installed over the pool water surface in the summer of 1982. The beneficial effect of these fans is experienced by the attendees of pool side exercise classes. Increased comfort is just one of the benefits of the system.

Psychrometrically, the increase of motion of the air directly impinging on the water's surface would cause an increase in the evaporation rate of the pool water. This in turn would require more makeup water to replace the water lost through evaporation. The relative humidity would increase in the pool area and as it surpassed 65%, the pool makeup air multi-zone system would run continuously introducing 100% outside air until the relative humidity dropped back down below 65%. It is plausible that the systems may have to run continuously which would account for the fact that no dramatic drop in weather sensitive natural gas consumption was experienced as was the case in the North Surrey Pool.

The non-weather sensitive component of the natural gas consumption dropped 32%. This component would primarily consist of pool water heating, domestic hot water consumption and reheat energy. In December 1982, the pool heater at the South Surrey Pool was put under the control of the BMS. This could account for the dramatic reduction in non-weather sensitive natural gas consumption which is supported by the reduction in complaints of water temperatures being too warm or too cold.

The electricity consumption increased about three percent in response to increased operating hours.

V. CONCLUSIONS

1. This demonstration has shown that an automated BMS can be very cost-effective if applied to the proper building. For example, the installation in the Municipal Hall and the North and South Surrey Pools was cost-effective and showed simple paybacks of three years or less, in the RCMP and Justice Buildings the System was definitely not cost-effective.

Before any installation, buildings must be properly and accurately audited to determine where energy is used; how much is used and what can be done to reduce energy use. There may be a range of less costly methods available to reduce energy use. For example, in the Justice and RCMP buildings a four channel load programmer could have been installed for about \$5,000 to effect similar energy savings as achieved by the BMS.

2. A BMS will provide the following advantages over alternative methods in addition to speed and efficiency which are the computers' major characteristics:
 - o Centralized control of building functions. Manpower can be deployed more efficiently and buildings can be controlled by staff who can program the system from one central location.
 - o Continuous monitoring of the building function. This serves as a preventive function - isolating minor problems before they escalate.
 - o Historical trend logging. Enables an analysis of individual building performance and assists in determining whether energy use systems should be expanded or altered in any way.
 - o Reduced staff travelling time. This may be a significant element in determining the benefits of BMS. Unfortunately, the benefits of reduced travel, reduced manpower requirements and possibly more efficient or better maintained systems have not been determined in this demonstration.
 - o Increased efficiency in a building's energy use systems.

3. The centralized control of widely distributed facilities can be cost-effective depending on the types of buildings controlled and their energy systems.

There are many alternative communication methods available to link the CPU to its field units - telephone lines are only one method, others include microwave, cable, etc. Each method will have advantages which must be considered in the overall feasibility study.

Conceivably a BMS could be provided as a service by private industry with "space" on the CPU being leased to the building owner as part of an overall contract.

The potential number of leasees would be technically restricted only by the capacity of the CPU.

VI. RECOMMENDATIONS

1. Develop a simple method to assist building managers to determine whether a BMS is a practical energy management alternative in a particular building. A brochure that describes a step-by-step approach to evaluating the feasibility of using a BMS in a particular building or a set of buildings would be useful. The reader could be shown how to perform the necessary calculations.
2. Develop criteria and a checklist for choosing a BMS, including a sample contract that ensures the responsibility for the systems operation and its compatibility with other systems rest with the supplier.
3. Provide financial support to demonstrate those systems that involve multiple users sharing or buying time on a system.
4. Perform further evaluations of BMS applications to determine what are some of the less obvious benefits and costs. Specifically, what are the impacts of a BMS on manpower needs, operating costs, including travel time and system performance including maintenance cost.

APPENDICES

APPENDIX A

Major Energy Use Systems (HVAC) in the Seven Demonstration Buildings

Municipal Hall

- o three pipe fan coil system with common return on perimeter of 2nd and 3rd floors.
- o rooftop single zone system c/w economizer provides ventilation air to 3rd floor.
- o main floor council chamber is served by a free standing air cooled DX fan coil (c/w economizer) terminal reheat system.
- o three pipe single zone serves committee and east rooms.
- o three pipe unit ventilator c/w economizer serves board room and personnel area.
- o built up 100% makeup air system located on lower main, main and 2nd floors.
- o lower main floor has a cafeteria with perimeter radiation.
- o one gas-fired hot water boiler and one centrifugal chiller are located in separate mechanical rooms on lower main floor.
- o six roof mounted fans provide exhaust capability.

Justice Building

- o variable temperature constant volume heat/cool system.
- o two split system DX air handlers with c/w economizers and air cooled condensing units provide the ventilation and cooling.
- o one split system services each floor.
- o one gas-fired hot water boiler.
- o perimeter hot water radiation.
- o roof mounted fans provide exhaust.

Whalley Library

- o one single zone gas-fired heat/cool rooftop c/w economizer serves the mezzanine.
- o two single zone rooftop units serve the ground floor entry and stair areas.
- o three roof mounted fans provide exhaust.
- o two electric entrance heaters.

Centennial Library

- o one gas-fired rooftop multizone (AH1) c/w economizer serves the ground floor library.
- o one gas-fired heat/cool single zone rooftop unit (AH2) c/w economizer serves the mezzanine floor.
- o three gas-fired heat/cool single zone rooftops (AH4, 5, and 6) serve the multipurpose room.
- o one gas-fired heat/cool single zone rooftop (AH3) serves the Chamber of Commerce.
- o gas-fired domestic hot water heater.

North Surrey Pool

- o one single zone heating and ventilating unit (HV1) c/w economizer serves the pool area.
- o one single zone heating and ventilating unit (HV2) c/w economizer serves the administration area, gallery and the male dressing room is served through a reheat coil.

South Surrey Pool

- o indoor multizone heating/ventilating unit (AH1) c/w economizer serves the pool area.
- o one single zone heating/ventilating unit (AH2) serves the training room and whirlpool area.
- o one axial return air fan.

- o one gas-fired heat/cool rooftop multizone unit c/w economizer serves the offices, change rooms and weight room.
- o eight exhaust fans.
- o six ceiling fans in pool area.

RCMP Building

- o one single zone DX split system air handler c/w air cooled condensing unit serves the 1st floor.
- o one single zone DX split system air handler c/w air cooled condensing unit serves the top floor.
- o two return air fans.
- o one rooftop cooling only unit mounted beside the building on a sleeper serves the radio room.
- o one single room air handler serves cell area.
- o 4 gas-fired hot water boilers located in the penthouse mechanical room provide hot water for the perimeter radiation.

MILIDIN'S

MUNICIPAL HALL	JUSTICE BUILDING	WINDLEY LIBRARY	CENTENNIAL LIBRARY	N. SURREY POOL	S. SURREY POOL	RCPM BUILDING
- Main fan - Roof top fan - Council Chamber fan coil - Council Chamber cooling	1st Floor Fan 2nd Floor Fan	- Entry rooftop unit - Stair rooftop unit - Upper rooftop unit	- Chamber of Commerce rooftop room rooftop - Library multi-zone & single zone rooftop	- Pool heating/ventilating unit - Administration heating ventilating unit - Pool heater	- Pool multizone air handling units - Training & whirlpool single zone Admin. rooftop multizone - Pool lighting - Pool heating pump - Pool heater	- Radio Room Fan 1st Floor Fan - Cell Fan 2nd Floor Fan
DUTY CYCLING	1st Floor Fan 2nd Floor Fan	- Entry rooftop unit - Stair rooftop unit - Upper rooftop unit	- Chamber of Commerce rooftop room rooftop - Library multi-zone & single zone rooftop	- Pool heating/ventilating unit - Administration heating/ventilating unit	Pool air handling Training & whirlpool air handling Admin. rooftop multizone	1st Floor Fan - Cell Fan 2nd Floor Fan
SUPPLY AIR RESET	- Main fan - Roof top fan - Council Chamber fan coil	1st Floor Fan 2nd Floor Fan	- Entry rooftop unit - Stair rooftop unit - Upper rooftop unit	- Chamber of Commerce rooftop room rooftop - Library multi-zone & single zone rooftop	- Pool heating/ventilating unit - Administration heating ventilation unit	Pool air handling Training & whirlpool handling Administration rooftop multi-zone
STREET LIGHTS				Pool heater	Pool heater	
OPTIMAL STOP/START	- Main fan - Roof top fan - Council Chamber fan coil	1st Floor Fan 2nd Floor Fan	- Entry rooftop unit - Stair rooftop unit - Upper rooftop unit	- Chamber of Commerce rooftop - Multipurpose room rooftop - Library multi-zone & single zone rooftop	Pool air handling Training & whirlpool air handling Administration rooftop air handling	
DEMAND LIGHTING						

APPENDIX C

Illustration of Normalization for Weather Differences

<u>Period</u>	<u>Degree Days (C)</u>
May 1981 - April 1982	3066.9
Sept. 1982 - August 1983	2725.2
30 Year Average	3030.7

Sample Calculation using Municipal Hall

$$\begin{array}{l} \text{Normalized Weather} \\ \text{sensitive component} \end{array} = \frac{\text{Raw Weather sensitive component}}{\text{Degree Days for actual period of analysis}} \times \begin{array}{l} \text{Degree Days} \\ \text{in Vancouver} \\ \text{for standard} \\ \text{year} \end{array}$$

$$\text{Raw Total Fuel use} = 716,557 \text{ EKWH}$$

$$\text{Non-weather sensitive use} = 332,448 \text{ EKWH}$$

$$\text{Raw weather sensitive use} = 716,557 - 332,448 = 384,109 \text{ EKWH}$$

$$\begin{array}{l} \text{Normalized weather} \\ \text{sensitive component} \end{array} = \frac{384,109}{2725.2} \times 3030.7 = 427,168 \text{ EKWH}$$

Total Normalized Usage

$$\text{Normalized weather-sensitive n.gas component} = 427,168 \text{ EKWH}$$

$$\text{Non-weather sensitive n.gas component} = 332,448 \text{ EKWH}$$

$$\text{Electricity} = \underline{1,095,264} \text{ KWH}$$

$$\text{Total Consumption:} \quad 1,854,880 \text{ EKWH}$$

$$\begin{array}{l} \text{Normalized index} = \underline{1,854,880} \\ 4972\text{m}^2 \end{array} \quad 373.1 \text{ EKWH/m}^2\text{.year}$$

TABLE 2 SUMMARY OF ENERGY CONSUMPTION FOR 12 MONTH PERIOD
BEFORE (May 81 - April 82) AND AFTER (Sept. 82 - Aug. 83) BMS INSTALLATION

BUILDING	NATURAL GAS (EKWH)					ELECTRICITY (KWH)			TOTAL (EKWH)		% CHANGE
	Norm. Weather Sensitive		% Change	Non-Weather Sensitive		Before	After	% Change	Before	After	
Municipal Hall	597,664	427,168	- 28.5	763,176	332,448	1,494,150	1,095,264	- 26.7	2,854,990	1,854,880	- 35
Justice Bldg.	-	-	-	-	-	128,142	118,056	- 7.9	128,142	118,056	- 7.9
Malley Lib.	98,950	62,431	- 36.9	9,108	3,732	307,463	277,090	- 9.9	415,521	343,253	- 17.4
Centennial Library	194,281	140,956	- 27.4	14,652	5,424	657,772	560,352	- 14.8	866,705	706,732	- 18.9
N. Surrey Pool	2,176,834	1,058,698	- 51.4	938,364	1,596,960	1,826,900	1,880,542	10.0	4,942,098	4,536,200	- 8.2
S. Surrey Pool	994,144	1,031,830	3.8	1,605,876	1,092,612	827,263	855,429	3.4	3,427,283	2,979,871	- 13.1
RCMP Building	-	-	-	-	-	661,665	648,846	- 1.9	661,665	648,846	- 1.9
Justice & RCMP Bldg. Combined	672,214	643,880	- 4.2	437,280	364,248	-	-	-	1,109,494	1,008,128	- 9.1

- Notes:
1. Both natural gas and electricity consumptions have been normalized to reflect meter reading differences.
 2. Natural gas consumption has been divided into weather sensitive and non-weather sensitive components with the former being normalized for annual degree day differences.
 3. Degree Days used are degrees below 18°C for Vancouver International Airport.

BUILDINGS

DEMAND LIGHTING	OPTIMAL STOP/START	SUPPLY RESET	SUPPLY AIR RESET	DUTY CYCLING	STOP/START	MUNICIPAL HALL	JUSTICE BUILDING	WHALLEY LIBRARY	CENTENNIAL LIBRARY	N. SURREY POOL	S. SURREY POOL	ROMP BUILDING
	- o Main fan - o Rooftop fan - o Council Chamber fan coil	- o 1st Floor Fan - o 2nd Floor Fan	- o Entry rooftop unit - o Stair rooftop unit - o Upper rooftop unit	- o Chamber of Commerce rooftop - o Multipurpose room rooftop - o Library multi-zone & single zone rooftop	- o Pool heating/ventilating unit - o Administration heating/ventilating unit - o Pool heater	- o Main fan - o Rooftop fan - o Council Chamber fan coil - o Council Chamber cooling	- o 1st Floor Fan - o 2nd Floor Fan	- o Entry rooftop unit - o Stair rooftop unit - o Upper rooftop unit	- o Chamber of Commerce rooftop - o Multipurpose room rooftop - o Library multi-zone & single zone rooftop	- o Pool heating/ventilating unit - o Administration heating/ventilating unit - o Pool heater	- o Pool air handling - o Training & whirlpool air handling - o Admin. rooftop multizone	- o Radio Room Fan - o 1st Floor Fan - o Cell Fan - o 2nd Floor Fan
	- o Main fan - o Rooftop fan - o Council Chamber fan coil	- o 1st Floor Fan - o 2nd Floor Fan	- o Entry rooftop unit - o Stair rooftop unit - o Upper rooftop unit	- o Chamber of Commerce rooftop - o Multipurpose room rooftop - o Library multi-zone & single zone rooftop	- o Pool heating/ventilating unit - o Administration heating/ventilating unit - o Pool heater	- o Main fan - o Rooftop fan - o Council Chamber fan coil - o Council Chamber cooling	- o 1st Floor Fan - o 2nd Floor Fan	- o Entry rooftop unit - o Stair rooftop unit - o Upper rooftop unit	- o Chamber of Commerce rooftop - o Multipurpose room rooftop - o Library multi-zone & single zone rooftop	- o Pool heating/ventilating unit - o Administration heating/ventilating unit - o Pool heater	- o Pool air handling - o Training & whirlpool air handling - o Admin. rooftop multizone	- o Radio Room Fan - o 1st Floor Fan - o Cell Fan - o 2nd Floor Fan